RADFET Ground Calibration and BioRADFET Experiment

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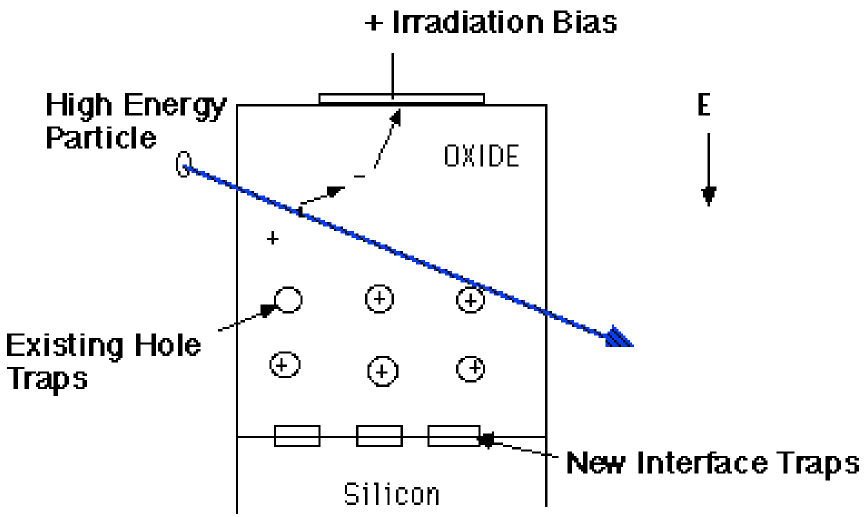
Outline:

- What is RADFET and how does it work?
- RADFET characterisation
- BioRADFET project
- Recent success story

RADFET operating principle:



- Radiation creates electron-hole pairs
- Initial recombination of electrons and holes happens
- Non-recombined electrons leave the oxide;
  holes are trapped in the vicinity of the oxide/silicon interface
- RADFET threshold voltage (V_T) changes ($\Delta V_T \sim$ Dose)

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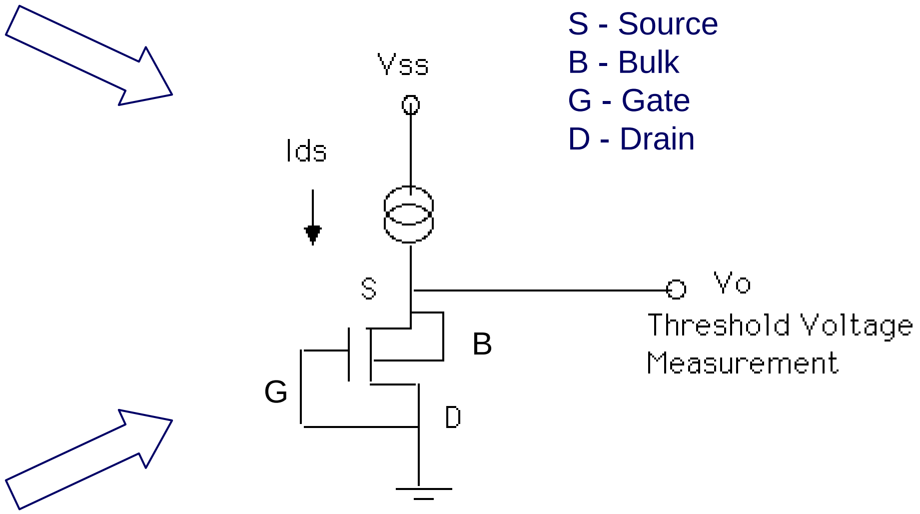
RADFET biasing configurations:

- Irradiation (sense mode): zero current; (B, S and D grounded); G can be:
  - Grounded ($V_{IRR}=V_{GS}=0V$)
  - Biased (typically $V_{IRR}=V_{GS}>0$)

  Read-out mode: specified current ($Ids=I_O$) applied to S=B; G=D grounded



- Irradiation (sense mode) and Read-out mode are the same

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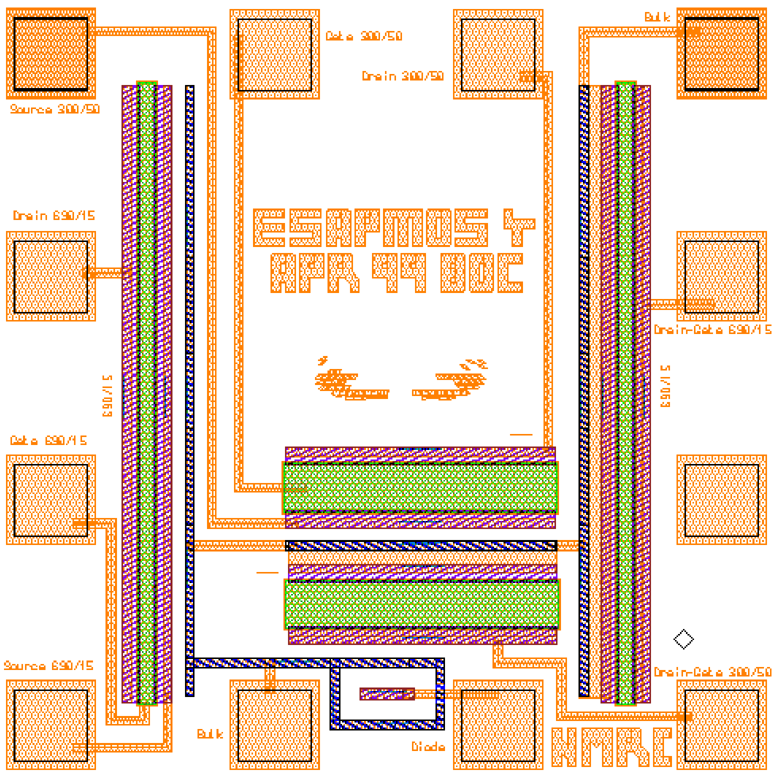
RADFET advantages over other dosimeters:

- Immediate read-out without destroying the data
- Extremely small sensor chip
- Very low or zero power consumption
- Technology suitable for connection to a microprocessor
- Comparatively low cost

Applications:

- Nuclear industry and research
- Space dosimetry
- Radiotherapy
- Personal dosimetry [?]

ESAPMOS4 RADFET chip:



- Chip size: 1mm x 1mm
- Contains four RADFETs:
  - two 300/50 devices
  - two 690/15 devices
- Chip types (gate oxide):
  - 100 nm
  - 400 nm
  - 400 nm Implanted (IMPL)
  - 1 µm
  - 1 µm Implanted (IMPL)

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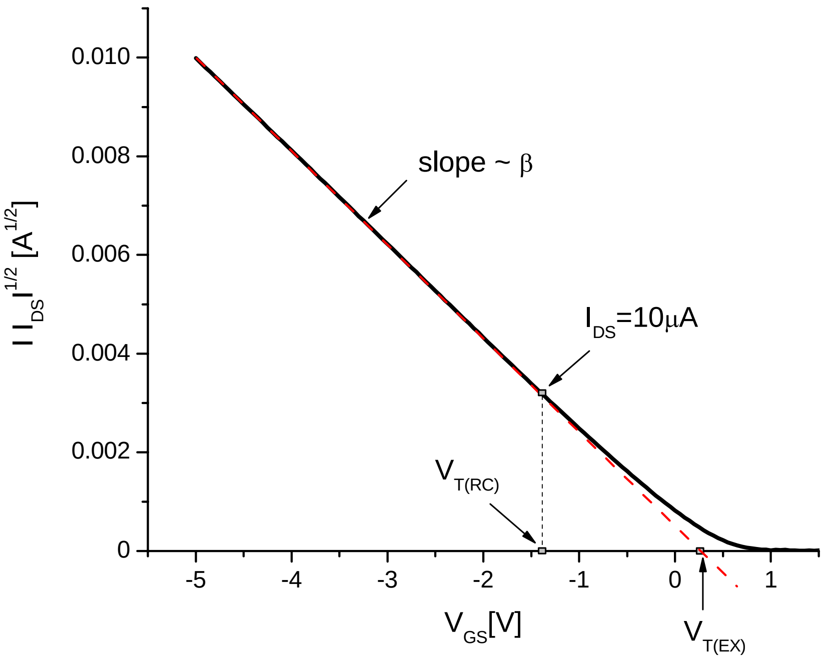
Pre-irradiation characterisation RADFETs:

Device type	$V_{T(RC)}$ @ 10µA [V]	$V_{T(EX)}$ [V]	β [× 10^{-6} A/V^2]	SS [mV/decade]
300/50 standard	-1.524 ± 0.124	0.193 ± 0.111	6.947 ± 0.127	263 ± 8
300/50 passivated	-1.630 ± 0.097	0.092 ± 0.105	6.986 ± 0.167	254 ± 9
690/15 standard	-0.201 ± 0.084	0.293 ± 0.072	75.370 ± 1.288	228 ± 5
690/15 passivated	-0.330 ± 0.067	0.148 ± 0.064	78.130 ± 1.956	225 ± 6



- No effect of passivation on pre-irradiation characteristics
- Changes in $V_{T(RC)}$ and $V_{T(EX)}$ are the same
- Changes in $V_{T(RC)}$ for different read-out currents are the same

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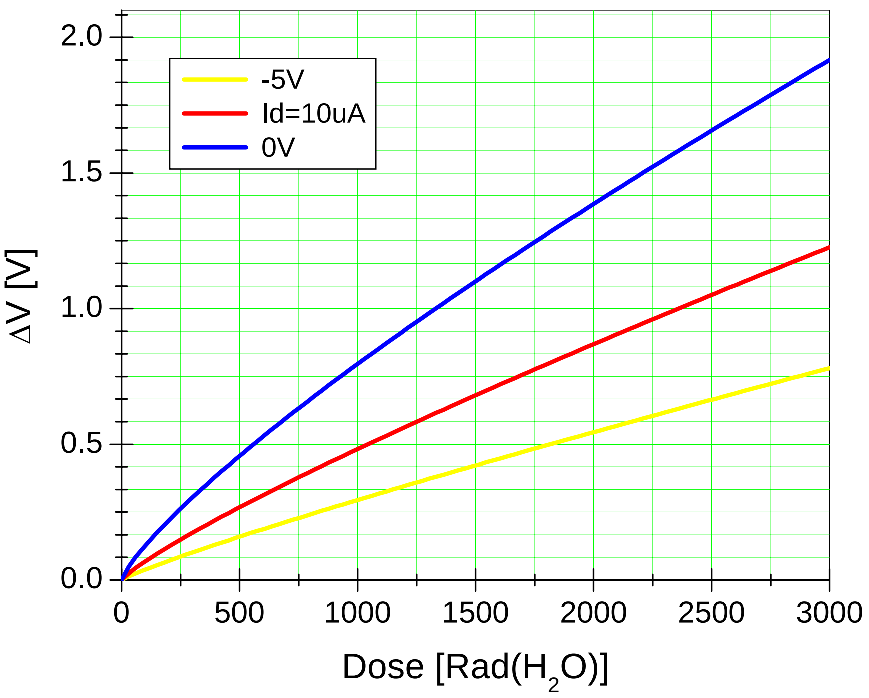
Passivation effect on radiation response:

- Sensitivity after 200cGy Co-60 dose:
  - Unpassivated RADFETs: ~0.55mV/rad
  - Passivated RADFETs (200nm Si_3N_4): ~0.75mV/rad
  - Passivated RADFETs , passivation stripped: ~0.55mV/rad
  - Passivated RADFETs, passivation stripped + CVD oxide: ~0.70mV/rad
- Main culprits: hydrogen and/or stress

Co-60 calibration curves (400nm IMPL):



Calibration coefficients

The curve equation is of the form: $\Delta V = a \times Dose^b$; ΔV[Volts], Dose[Rad(H_2O)].

Bias	a	b	R-square	SSE
-5V	0.000643	0.8871	0.9999	0.00042
Cont Id=10μA	0.001365	0.8494	0.9994	0.00475
0V	0.003166	0.8001	0.9976	0.04626

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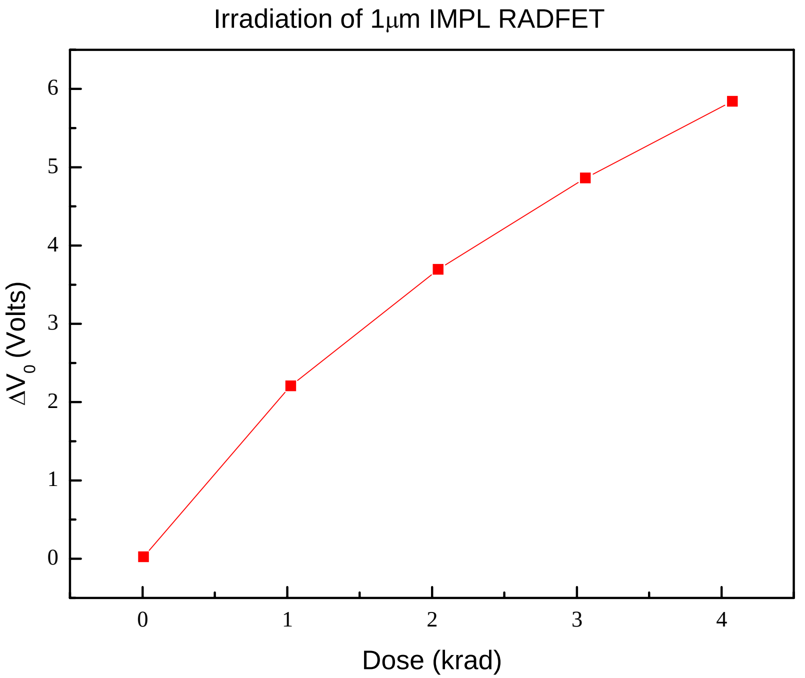
Co-60 irradiation (1μm IMPL):



- Preliminary radiation data (courtesy Avner Haran, Soreq NRC)
- Most sensitive non-stacked RADFET up to date
- Initial threshold voltages very uniform, fading low

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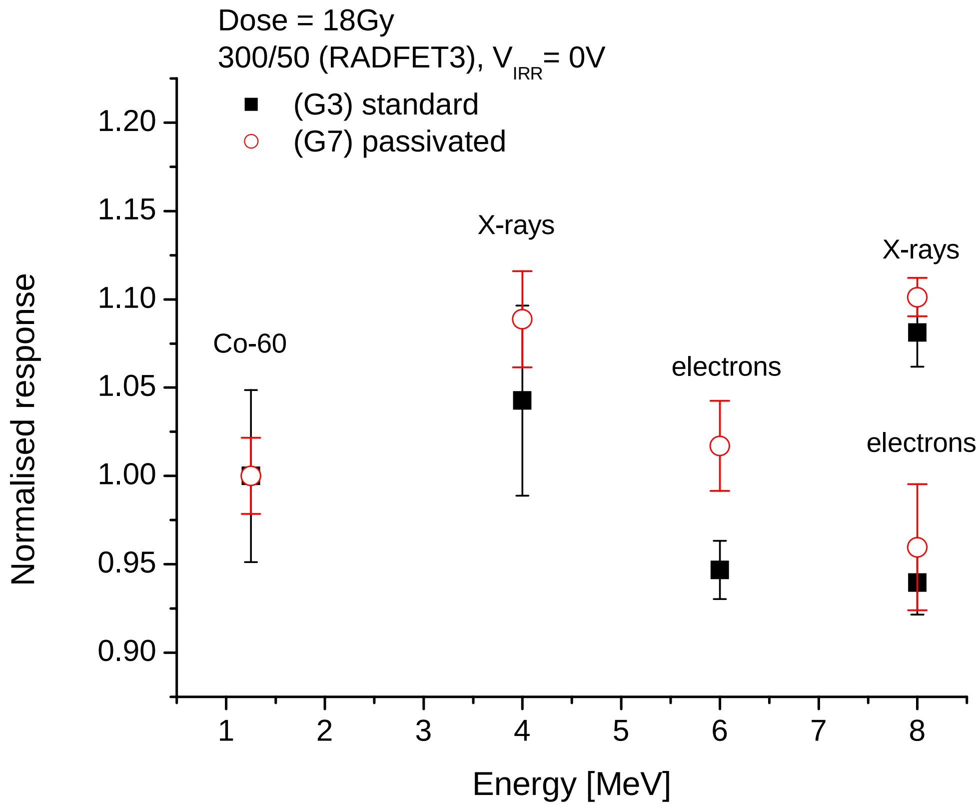
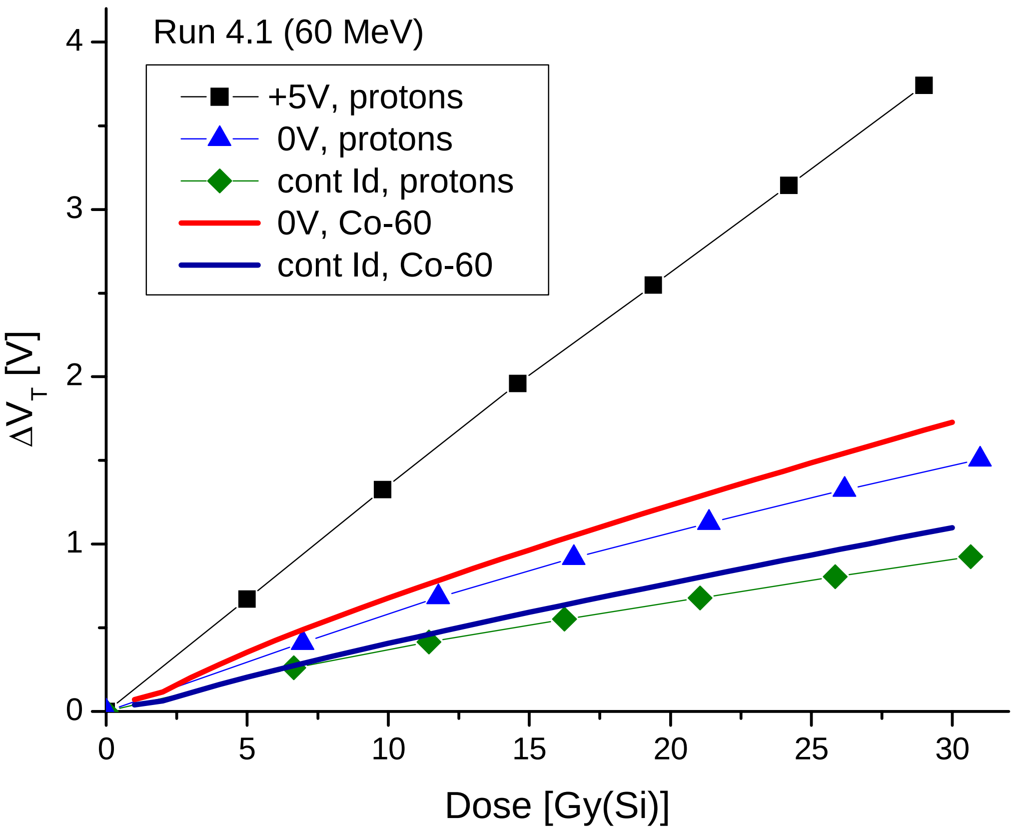
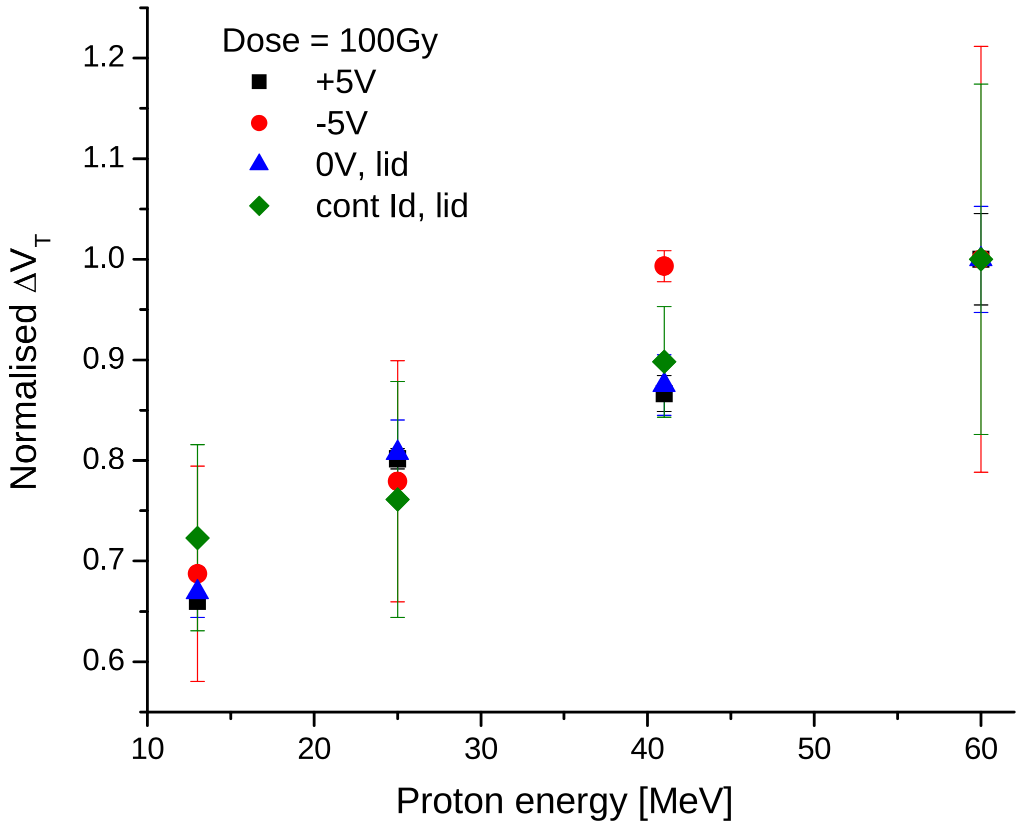
Electron irradiation (zero V_{IRR}, normalised):



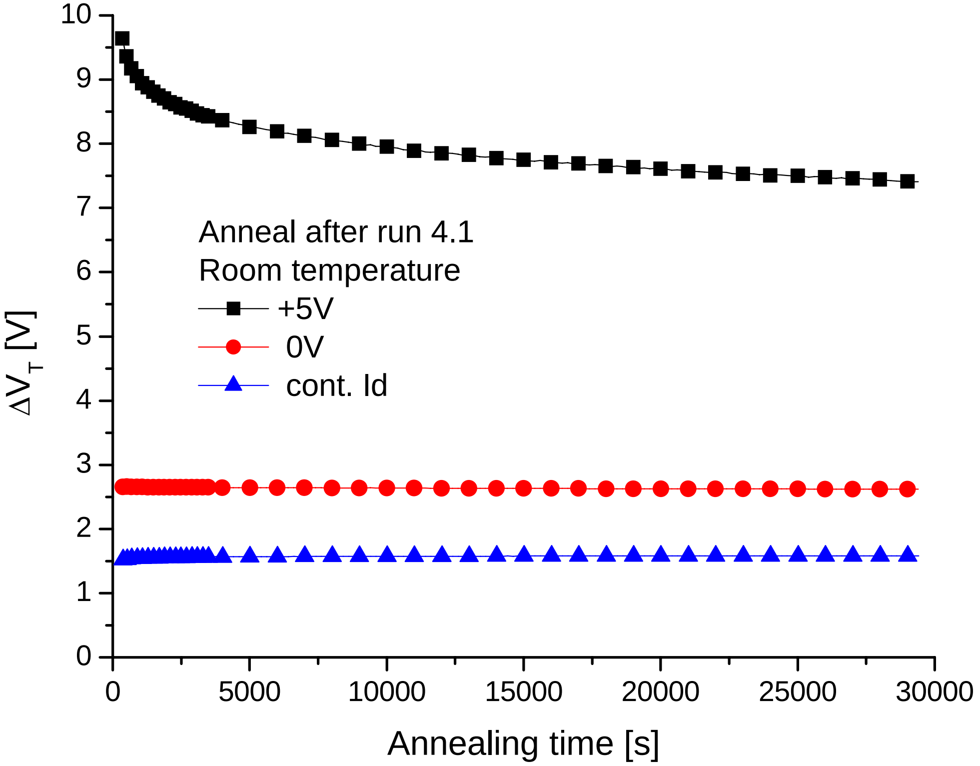
Proton irradiation:



Proton energy dependence (normalised):



Post-irradiation annealing (fading):



- Proton data shown, similar data for other types of radiation

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Irradiation response summary:

- Flat energy response to photons and electrons (1-8MeV)
- Energy dependent response to protons (10-60 MeV)
- Preferred biasing configurations:
  - Zero gate bias (V_{IRR}=0V)
    - ✓ Good sensitivity
    - ✓ Low fading
    - × Need to switch between irradiation and read-out mode
  - Continuous I_o
    - × Somewhat decreased sensitivity
    - ✓ Low fading
    - ✓ No need for switching between irradiation and read-out mode

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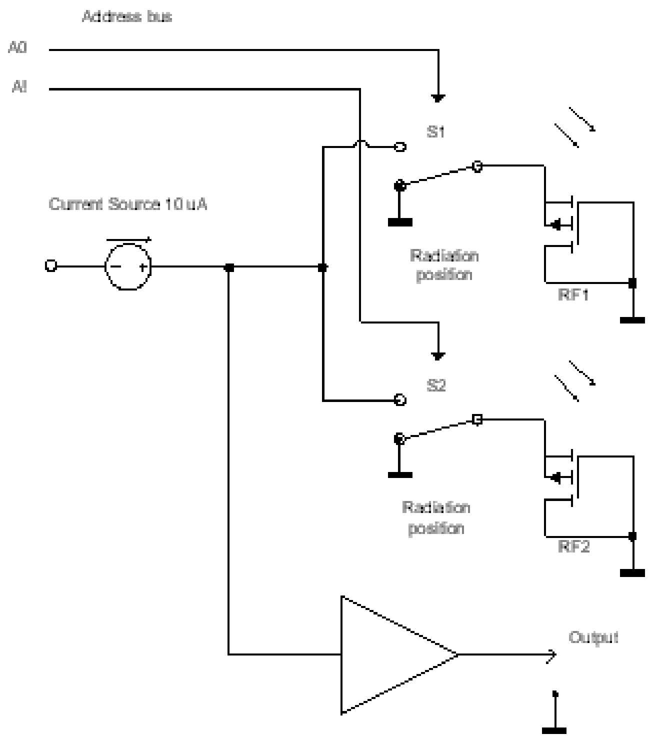
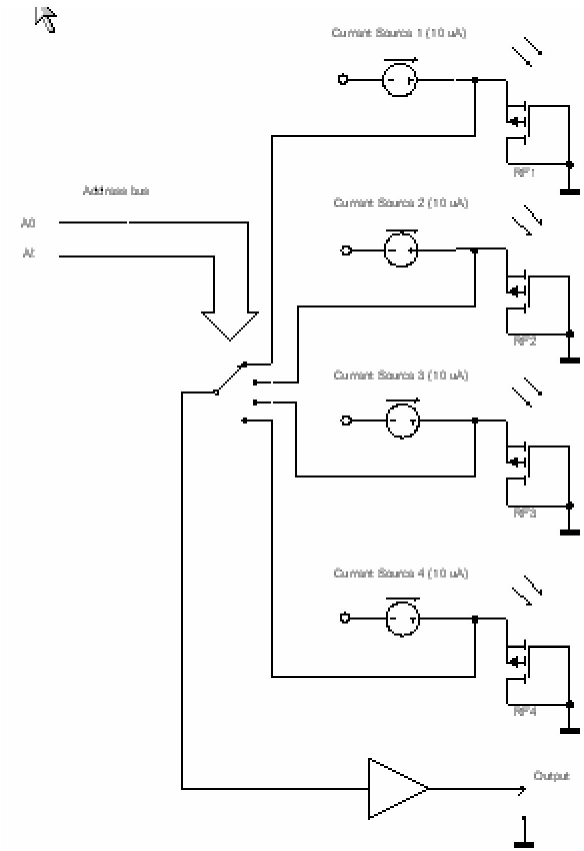
BioRADFET project:

- Part of the Biopan-5 experiment on Photon-M2
- Lounch scheduled for Wednesday next week
- RADFET reader board (BioRADFET)
  - DC power supply: 12V (continuous)
  - Maximum current: 0.5mA
  - Two TTL control lines to control multiplexer/switches

BioRADFET configurations considered:

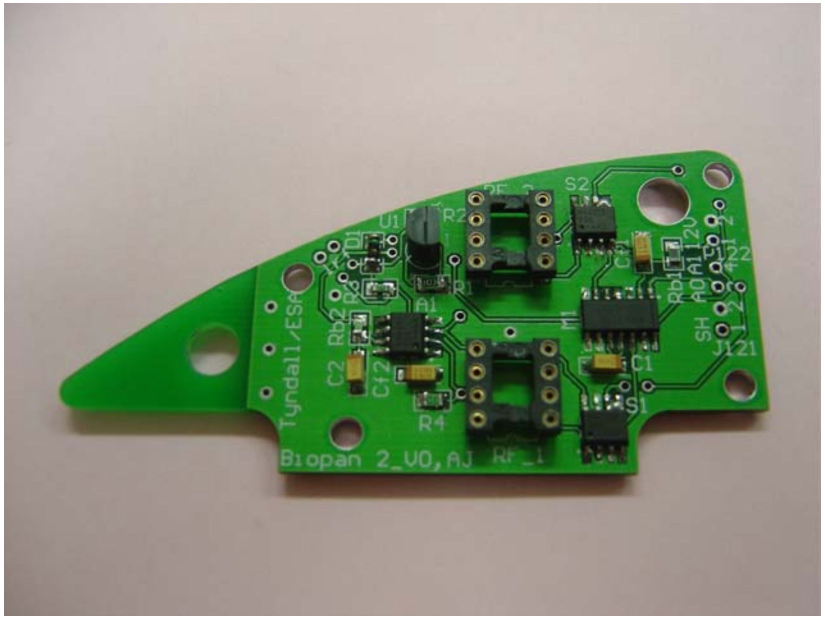


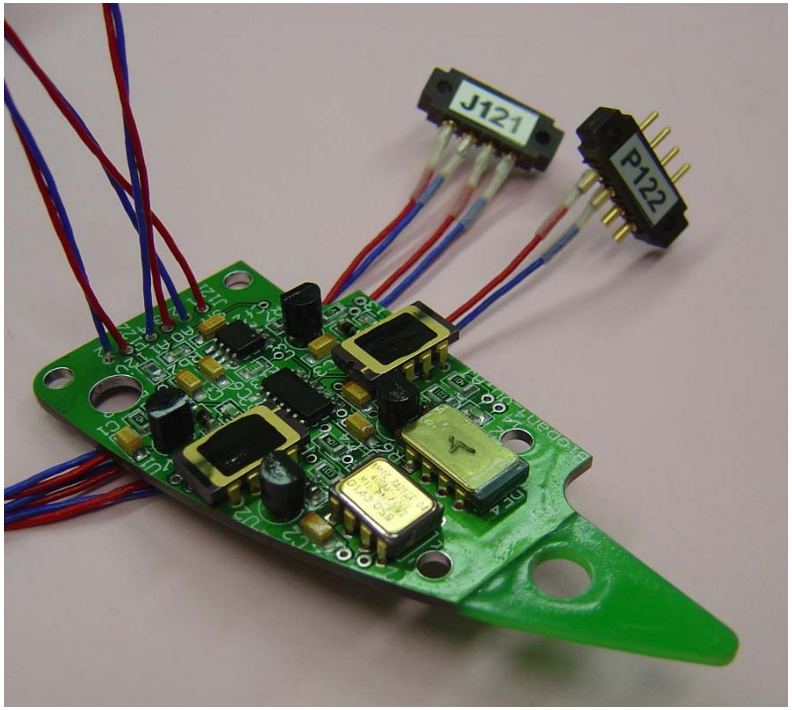
Zero V_{IRR}



Continuous I_O

BioRADFET boards manufactured:





Zero V_{IRR}

Continuous I_O

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Recent success story:

- RADFET development under ESA sponsorship since late 1980s
- Applications: space (ESA, other agencies), particle physics labs.
- New application: QA of radiotherapy treatments
  - OneDose system developed by Sicel Technologies (surface dosimetry)
  - DVS system under development (implantable dosimetry)

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